RESEARCH ARTICLE

The Status and Management of Exotic and Invasive Species in National Wildlife Refuge Wilderness Areas

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ABSTRACT: On behalf of the U.S. Fish and Wildlife Service (USFWS), we surveyed agency personnel in 2001 to assess the status and management of invasive plants, exotic animals, and exotic pathogens within the agency's federally designated wilderness areas. We surveyed wilderness areas because they serve as important ecological reference points for natural systems due to their protected status. Respondents from 68 of the 70 USFWS wilderness areas completed the survey. Exotic animals were deemed a major problem (i.e., one of the top 10 management priorities) in 32% of the wilderness areas surveyed. Invasive plants were considered a major problem in 26% of the wilderness areas surveyed in the lower 48 states, but in none of Alaska's 21 wilderness areas. In contrast, respondents considered an exotic pathogen to be a major problem in only one wilderness area. Respondents in three USFWS Regions reported relatively large numbers of invasive species in wilderness: Region 2 (Southwest), Region 4 (Southeast), and Region 6 (Mountain-Prairie). Systematic field surveys had been conducted for invasive plants in 19% of the wilderness areas, for exotic animals in 18% of the areas, and for exotic pathogens in 10% of the areas. Respondents commonly cited a lack of staff and/or funding as a barrier to the implementation of monitoring and management programs. Therefore, we offer several suggestions to improve the management of invasive and exotic species in wilderness that would require few additional resources to implement. To facilitate the monitoring of trends and communication among managers, we made the results available in an Internet-accessible database <http://leopold.wilderness.net/links.htm>.

Index terms: control programs, exotic species, invasive species, monitoring, National Wildlife Refuges, non-native species, U.S. Fish and Wildlife Service, wilderness areas

INTRODUCTION

Within the past two centuries, the human-mediated dispersal of species into new regions of the world has greatly increased in scale and magnitude, and is expected to intensify in future years due to the increasing globalization of travel and commerce (Baskin 2002). Some of these introduced species become naturalized in their new locations, expand their ranges, and ultimately have dramatic effects on both natural systems and human economies (Simberloff et al. 1997, Cox 1999).

Invasive species are considered a major threat to the conservation of biodiversity. For example, invasive species threaten 57% of plants, 53% of fishes, and 47% of terrestrial vertebrates that are "imperiled" in the United States (Wilcove et al. 1998). Invasives compete with, prey upon, and cause disease in native species, and alter large-scale ecological processes to the detriment of native species (Cox 1999). In addition, the economic costs stemming from invasive species have been estimated at nearly $137 billion per year in damages and control costs alone (Pimentel et al. 2000).

In response to growing concerns about invasive species, the U.S. Fish and Wildlife Service (USFWS) made the monitoring and management of invasive species a high priority (U.S. Fish and Wildlife Service 1999). In 2001, the USFWS requested the Aldo Leopold Wilderness Research Institute (Leopold Institute) to survey agency personnel responsible for managing federally designated wilderness areas. With this survey, we collected information on invasive and exotic species known to occur within designated USFWS wilderness areas, as well as the problem severity and the management actions being taken to monitor and control them.

Wilderness areas were chosen for the initial survey because they are relatively undisturbed by human activity and must be managed to maintain their natural conditions. As a result, they serve as important ecological reference points for other natural areas and may be critical for the maintenance of native biodiversity.

SURVEY METHODS

In April 2001, we mailed packets containing a survey form, a list of noxious weeds found in the appropriate state, and a memorandum from the Chief of the National Wildlife Refuge System to the Regional Chiefs, who then distributed the packets to all Refuges containing wilderness. The noxious weed lists were intended to facilitate the completion of the survey.

In most cases, wildlife biologists, refuge managers, and assistant refuge managers completed the surveys. We received all completed surveys by September 2001. When necessary, we made follow-up phone calls to encourage survey completion or to clarify or obtain information missing from a completed survey. The survey form, a list of the participating wilderness areas, and the survey data are available on the Internet at <http://leopold.wilderness.net/links.htm>.

We asked survey respondents a variety of questions about the status and management of invasive and exotic species within wilderness, as well as a few questions concerning the entire Refuge. During data analysis, the questions were grouped into the following general categories: species' presence and distribution, problem severity, monitoring/information quality, and management actions. It must be noted that definitions were not provided to the survey respondents, and individual respondents may have had differing interpretations for terms such as "invasive" and "exotic." Our results, however, still indicate general patterns of invasive and exotic species occurrence throughout the USFWS wilderness system.

SURVEY RESULTS

We attribute the survey's 97% response rate (68 of 70 USFWS wilderness areas) to its top-down distribution within the Refuge System, which imparted a sense of importance to its completion. Region 7 (Alaska) contained the greatest number of responding wilderness areas (n = 21), comprising over 90% of the total USFWS wilderness land area. Region 4 (Southeast) contained the second greatest number of responding areas (n = 16), half of which were located in Florida. The remaining wilderness areas were evenly distributed among the other Regions (Figure 1a). Region 2 (Southwest) contained the majority of the wilderness acreage in the lower 48 states (Figure 1b), primarily due to the Kofa Wilderness and Cabeza Prieta Wilderness.

Management concerns, monitoring efforts, and control measures for invasive plants and exotic animals differed substantially between Alaska and the lower 48 states. These results may have been due to geographic location, human use, and historical differences between wilderness areas in the two regions. Thus, we present survey results separately for Alaska and the lower 48 states.

Species Presence

The 68 USFWS wilderness areas reported 201 known occurrences of invasive and exotic species (162 plants, 62 animals, 7 pathogens). When a single species was present in multiple wilderness areas, we considered each case to be an occurrence. Ninety-five of these occurrences were of "special concern" to managers (66 plants, 26 animals, 3 pathogens). Invasive and exotic species, particularly invasive plants, were most prevalent in the Southwest, Southeast, and Mountain-Prairie Regions. These Regions reported at least twice as many total species and species of concern than other Regions (Table 1). Within the lower 48 states, however, these Regions had

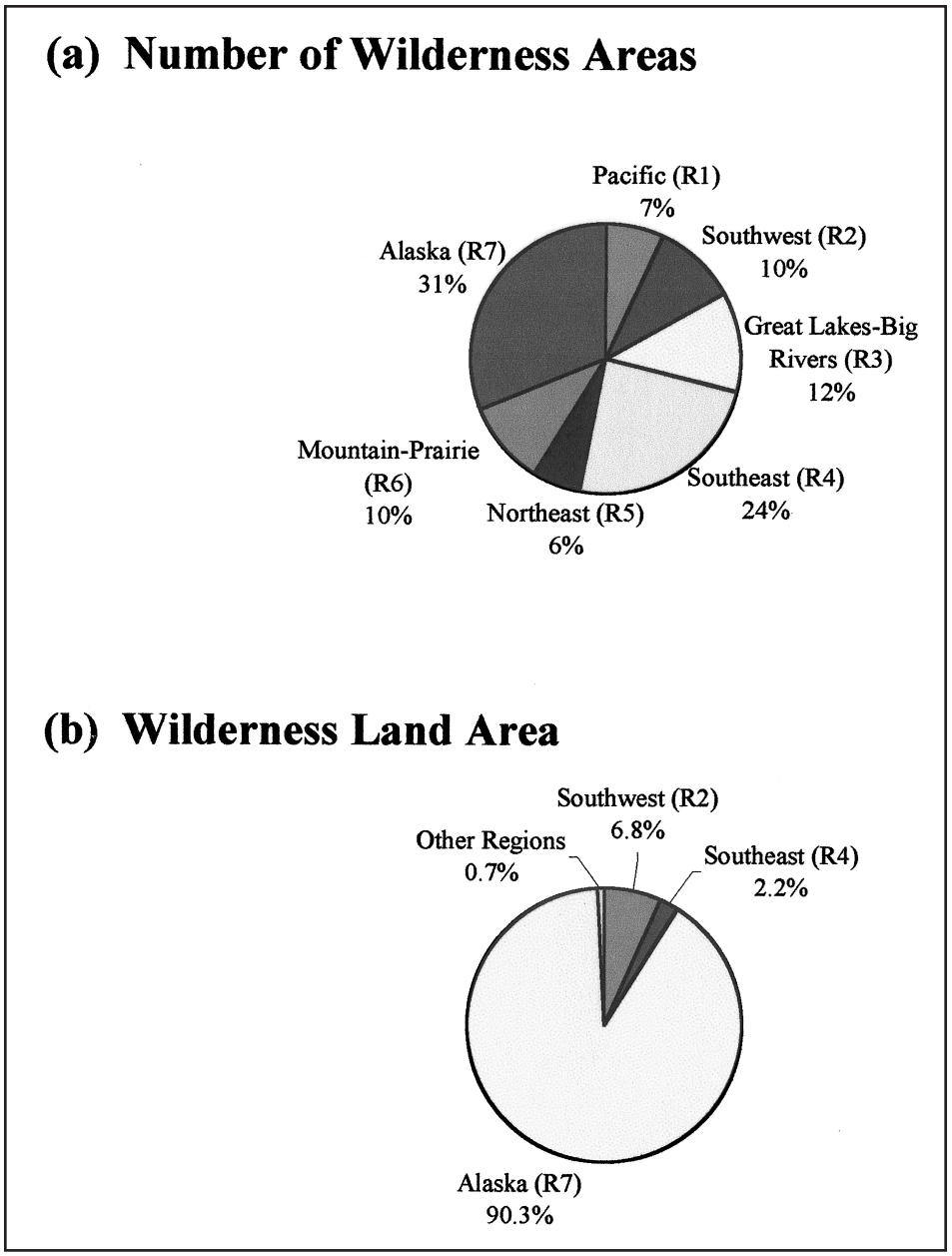

Figure 1. The percent by USFWS Region (R) of: (a) number of wilderness areas surveyed, and (b) wilderness acreage contained in areas surveyed.

more wilderness units and wilderness land area than the other Regions, contributing to the greater number of non-native species reported.

Problem Severity

We asked respondents to rate the severity of invasive plants and exotic animals and pathogens as a management problem, both within wilderness and within the entire Refuge. Their choices were: 1) very important, one of the top two or three problems, 2) significant, one of the top ten problems, 3) one of many small problems, and 4) not much of a problem.

Alaska respondents indicated that exotic animals were of greater concern than invasive plants (Figure 2a). Exotic animals were deemed a "very important" management problem for half of the wilderness areas, all of which are islands that serve as important breeding grounds for seabirds and waterfowl. Bird populations have been nearly extirpated from many islands due to historical, intentional releases of Arctic foxes (*Alopex lagopus*) and red foxes (*Vulpes vulpes*) for fur farming, as well as the unintentional introduction of Norway rats (*Rattus norvegicus*; Bailey 1993). On the other hand, all of the Alaska respondents considered invasive plants to be "not much of a problem."

In wilderness within the lower 48 states, 29% of the respondents thought that both invasive plants and exotic animals were either a "very important" or a "significant" management problem (Figure 2b). Within the entire Refuge, however, respondents were more concerned with invasive plants than exotic animals. Forty-eight percent of the respondents considered invasive plants to be a "significant" or "very important" problem, compared to 27% for exotic animals.

Many of the invasive plants reported in wilderness, however, have the potential to greatly alter ecosystem structure and function. These species include cheatgrass (*Bromus tectorum*), Lehmann lovegrass (*Eragrostis lehmanniana*), saltcedar (*Tamarix* spp.), Brazilian pepper (*Schinus terebinthifolius*), Chinese tallow (*Sapium sebiferum*), and Australian pine (*Casuarina equisetifolia*; Cox 1999). (Note: all plant names conform to U.S. Department of Agriculture [2002] nomenclature.) Several reported animal species have the potential to greatly affect native ecosystems and species as well, including the burro (*Equus asinus*), hog (*Sus scrofus*), nutria (*Myocastor coypus*), and brook trout (*Salvelinus fontenalis*).

Exotic pathogens were not considered a serious problem in either Alaska or the lower 48 states. About 90% of all respondents indicated that pathogens were "not much of a problem" in either wilderness or the entire Refuge. However, 10% of lower 48 respondents anticipated that pathogens would become a "significant" management problem in the next five years. Pathogens such as West Nile virus (birds) and chronic wasting disease (ungulates) have been recorded across the country within the last two years (Enserink 2002, Williams et al. 2002) and will be difficult to confine to areas outside of wilderness.

Monitoring and Information Quality

We asked respondents if they monitored invasive and exotic species in wilderness and, if not, to provide a reason. Their choices were: 1) not a significant problem; 2) cost prohibitive, lack of funding;

Table 1. The presence, severity, and control of invasive plants, exotic animals, and exotic pathogens in wilderness areas within each USFWS Region.

Region	# Areas	Total Area (ha)	Plants [a]	Animals [a]	Pathogens [a]	Total [a]
R1 (Pacific)	5	635	23/2/1 [b]	4/2/0	0/0/0	27/4/1 [b]
R2 (Southwest)	7	567,386	29/13/3	12/6/6	1/0/0	42/19/9
R3 (Great Lakes-Big Rivers)	8	17,507	8/4/2	10/3/0	0/0/0	18/7/2
R4 (Southeast)	16	186,991	28/24/5	14/6/6	3/0/1	45/30/13
R5 (Northeast)	4	8,162	9/8/1	2/0/0	2/2/0	13/10/1
R6 (Mountain-Prairie)	7	32,992	27/15/5	10/4/2	1/1/1	38/20/8
R7 (Alaska)	21	7,564,149	8/0/2	10/5/1	0/0/0	18/5/3
Total	68	8,377,822	132/66/19	62/26/15	7/3/2	201/95/36

[a] The first number is the overall number of invasive or exotic species reported, the second is the number of species of concern reported, and the third is the number of wilderness areas with active control programs. The species numbers were obtained by summing the totals for each wilderness area in a Region. Thus, if a single species was present in multiple wilderness areas, each occurrence was counted.

[b] The Oregon Islands Wilderness survey respondent considered all 17 exotic species found during a wilderness botanical survey to be invasive, the only case in which all exotic plant species were considered to be invasive. This may have inflated the number of invasive plant species recorded in R1 relative to the other Regions.

3) labor prohibitive, lack of staff; 4) both cost and labor prohibitive; and 5) other. Respondents were also asked to provide the source of the information used to complete the survey: 1) systematic sampling, 2) casual or opportunistic observation, 3) best guess, and 4) other.

In Alaska wilderness areas, managers monitored exotic animals more often than invasive plants and exotic pathogens. Exotic animals were monitored in 62% of the wilderness areas; when monitoring did not occur, 50% of the respondents cited a lack of staff and funding. Invasive plants were monitored in 10% of the wilderness areas, and exotic pathogens were monitored in only 5%. Ninety percent of respondents stated that both plants and pathogens were "not a significant problem."

In lower 48 wilderness areas, invasive plants and exotic animals were monitored at similar rates (49% for plants, 46% for animals). Exotic pathogens were monitored only 14% of the time. For all three taxa, a large number of respondents did not monitor due to a lack of staff and/or funding (54% for plants, 50% for animals, and 36% for pathogens).

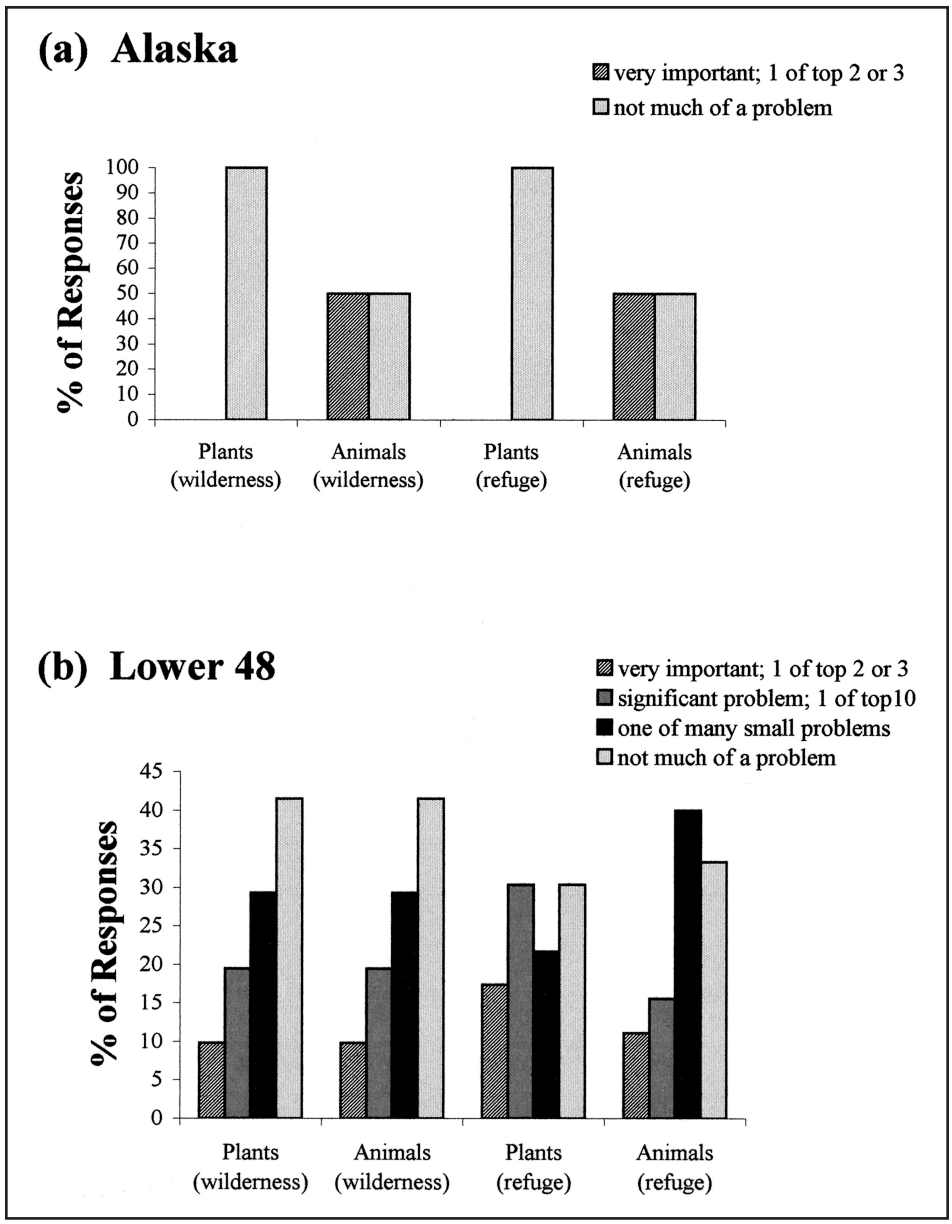

Figure 2. Importance of invasive plant and exotic animal management relative to other management issues in USFWS Refuges and wilderness areas in: (a) Alaska, and (b) the lower 48 states.

Survey responses were frequently based on casual or opportunistic observations and best guesses, rather than systematic sampling. Sampling was conducted in only 19% of all wilderness areas for invasive plants, 18% for exotic animals, and 10% for exotic pathogens, reducing the reliability of the information provided (Figure 3).

Respondents were also asked to rate the relative accuracy of the provided species lists on a scale of 1-5, with 1 being the least accurate and 5 being the most accurate. In Alaska wilderness areas, survey respondents had much greater confidence in their knowledge of exotic animals than invasive plants. Eighty-three percent of the respondents rated the information accuracy for exotic animals as a 4 or 5, whereas 67% rated the accuracy of their plant information as a 1 (Figure 4). This difference in perceived accuracy occurred despite the similarity of the information sources (i.e., best guesses and casual or opportunistic observations) for invasive plants and exotic animals (Figure 3).

In lower 48 wilderness areas, survey respondents were equally knowledgeable about invasive plants and exotic animals (Figure 4), in this instance reflecting the similarity of the information upon which the survey responses were based (Figure 3). Respondents again relied heavily on casual or opportunistic observations, but relied less on best guesses than Alaskans, who have greater difficulty in accessing wilderness.

Most respondents had little information on exotic pathogens in wilderness areas. Thirty-one percent of all respondents failed to rate the information quality for pathogens, presumably because an informed guess on the presence and distribution of pathogens was not possible. Furthermore, 74% of those who did provide a response rated the information accuracy for pathogens as a 1.

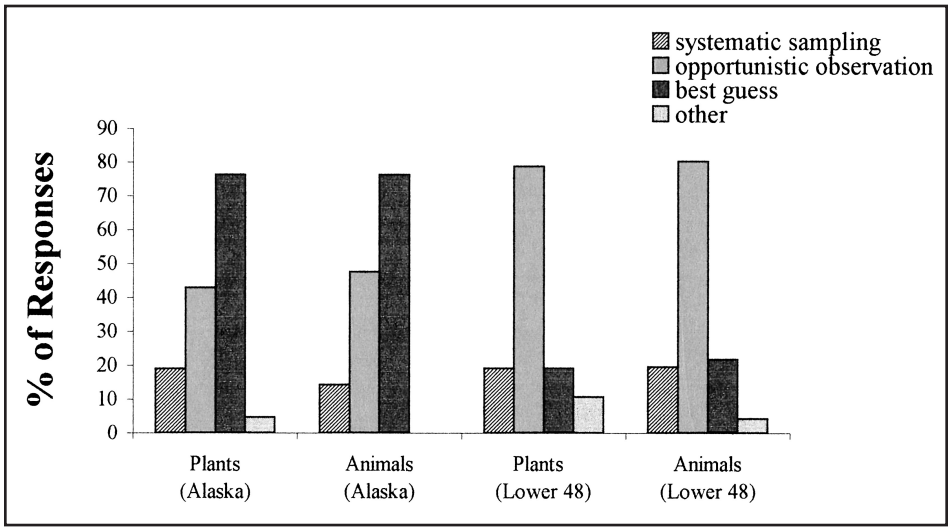

Figure 3. The source of the information provided by survey respondents.

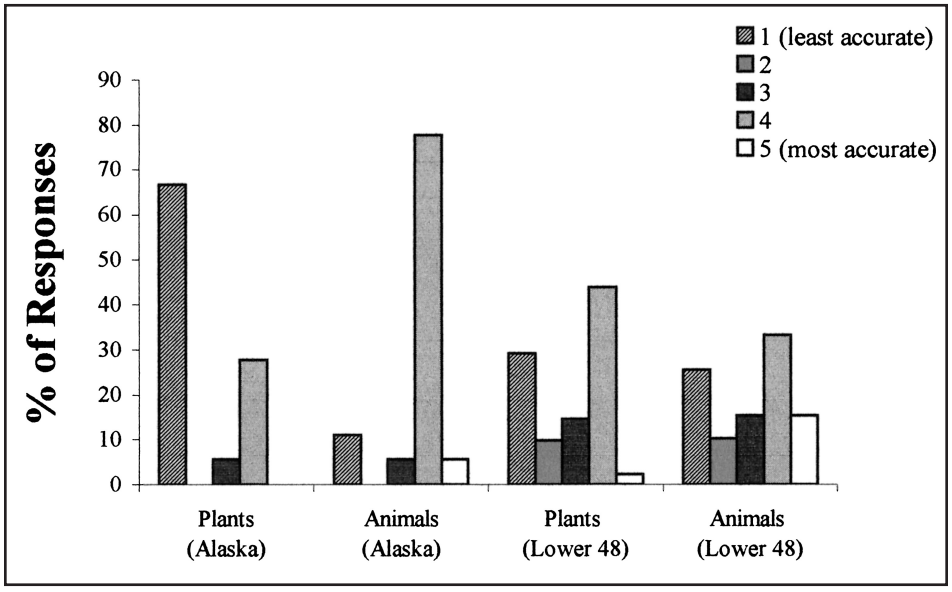

Figure 4. Survey respondents' confidence level in the information provided.

Management Actions

Management Plans

We asked respondents whether written management plans existed or were in progress for any invasive plant, exotic animal, or exotic pathogen species in wilderness, and, if not, to provide a reason. The available choices were the same as for lack of monitoring (see above).

In Alaska wilderness areas, exotic animal management plans existed for 48% of the areas. In contrast, no management plans had been written for invasive plants or exotic pathogens. When plans had not been written for either animals or plants, 48% of the respondents cited a lack of staff and/or funding. All of the respondents indicated, however, that pathogens were not a "significant" problem.

In lower 48 wilderness areas, written management plans were uncommon. Seventeen percent of the areas had plans for managing invasive plants, 15% for exotic animals, and 4% for exotic pathogens. Managers frequently did not write plans because of a lack of staff and/or funding. This frequency was 41% for plants, 44% for animals, and 32% for pathogens.

NEPA Analyses

A number of control efforts were underway in USFWS wilderness areas (Table 1). Overall, there were control programs for invasive plants in 27% of the wilderness areas, for exotic animals in 21%, and for exotic pathogens in 3%. Moreover, respondents thought these efforts were making a difference. When control efforts were being conducted, species of concern were thought to be decreasing in distribution in 33% of the cases.

With respect to control efforts in wilderness, we asked respondents whether a National Environmental Policy Act (NEPA) analysis had been completed before implementation of the program. NEPA requires that all proposals for Federal actions consider alternative courses of action and potential environmental impacts associated with each course of action. Depending on the nature of the action and its anticipated effects, NEPA documentation may be required (Bean and Rowland 1997).

For every control program in Alaska wilderness areas (all directed towards exotic animals), managers had completed environmental analysis documents. Control programs consisted entirely of lethal removal of introduced Norway rats (*Rattus norvegicus*) and Arctic foxes (*Alopex lagopus*) from islands. Within lower 48 wilderness areas, managers had completed environmental analysis documents for 33% of the control programs. NEPA documents were written for two types of control activities: 1) lethal and non-lethal removal of mammal species (burro, hog, nutria, and gemsbok [*Oryx gazella*]); or 2) integrated control programs for invasive plants incorporating both biological and chemical methods.

Minimum Tool Analyses

As stipulated in the 1964 Wilderness Act, managers are required to use only the minimum tool, regulation, or force necessary to accomplish wilderness management

objectives (Hendee and Dawson 2002). Similarly, USFWS policy (6 RM 8.2) requires that management actions undertaken in wilderness areas use the "minimum tools necessary to safely accomplish the Service's refuge objectives and preserve, to the extent practicable, the interaction of natural forces with the land." Minimum tool analysis is one way to document such decisions (see Arthur Carhart National Wilderness Training Center 2002). We asked respondents if a Minimum Tool Analysis had been completed for any existing control efforts. To control invasive plants, managers of 11 USFWS wilderness areas had used or were still using chemicals (as well as one use of chemicals for pathogen control), and six had released insects as biological control agents. A Minimum Tool Analysis was completed for only one (8%) of these plant control programs.

DISCUSSION

Invasive or exotic species were known to be present in every USFWS wilderness area, including remote oceanic islands, despite the lack of systematic surveys in most wilderness areas. Not surprisingly, many survey respondents cited a lack of funding and/or staff for their inability to survey and monitor invasive or exotic species, consistent with the response of wilderness managers from other agencies (Marler 2000). Without a greater financial commitment from Congress or the agency, all existing personnel (including non-biologists) should be trained to identify and, in the case of small infestations, properly remove targeted invasive species encountered during routine work duties. Undoubtedly, such action has already been implemented on many Refuges and should be implemented on all Refuges.

Most wilderness areas lacked management plans for invasive or exotic species, and respondents again commonly cited inadequate staff and/or funding. Refuge management has historically been guided by a number of management plans, written as pressing issues arose. The National Wildlife Refuge System Improvement Act of 1997, however, directed each Refuge to complete a Comprehensive Conservation Plan (CCP) by 2012. The CCP will govern all aspects of Refuge management (Gergely et al. 2000). Based upon our recent discussions with Refuge personnel regarding fire management, significant personnel resources have been allocated to Conservation Plan development. This presents an ideal opportunity to incorporate invasive species management plans into CCPs for many Refuges currently lacking such plans.

Minimum Tool Analyses were rarely conducted for invasive species control programs in wilderness, even those using chemicals and biological control agents, which can have unintended, adverse, and irreversible effects. We sympathize with managers who must react quickly to control invasive species, but appropriate management actions outside of wilderness are not always appropriate within wilderness. The 1964 Wilderness Act mandates that wilderness be managed to maintain "untrammeled" conditions, as well as natural conditions. Managers could better balance these potentially conflicting mandates by at least incorporating a Minimum Tool Analysis into future NEPA documents written for invasive species control programs in wilderness.

Encouragingly, respondents reported the successful eradication of invasive species from several small, isolated USFWS wilderness areas. While some efforts were resource-intensive (e.g., the eradication of introduced foxes from wilderness islands in the Alaska Maritime NWR; Ebbert 2000), other eradications were accomplished with few additional personnel or funds. For example, managers of the J. N. "Ding" Darling Wilderness, located on a portion of Florida's Sanibel Island, cooperated with local officials and a non-profit organization to eradicate melaleuca (*Melaleuca quinquenervis)* from the island and Australian pine from the wilderness area. In the Florida Keys Wilderness, a Refuge biologist (donating considerable amounts of his personal time) and volunteer citizens eradicated Australian pine and white leadtree (*Leucaena leucocephala*). Similar efforts may be possible in larger, mainland wilderness areas if invasions are detected at early stages.

Recognizing the need to manage invasive species more efficiently, the USFWS has identified the establishment of a reliable, standardized monitoring protocol as a Refuge System goal (U.S. Fish and Wildlife Service 1999). As a result, the agency is currently funding a major effort to develop a national protocol for surveying all USFWS Refuges for invasive species (NIISS 2004). Because wilderness areas provide an ecological reference for non-wilderness lands and may be critical to maintain native biodiversity, the national protocol should be designed to facilitate the comparison of wilderness and non-wilderness lands within the Refuge System.

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LITERATURE CITED

Arthur Carhart National Wilderness Training Center. 2002. Minimum requirement decision guide. Retrieved on December 17, 2003 from the World Wide Web. Available online <http://carhart.wilderness.net>.

Bailey, E.P. 1993. Introduction of foxes to Alaskan islands—history, effects on avifauna, and eradication. Resource Publication 193. U.S. Department of the Interior, Fish and Wildlife Service, Washington D.C.

Baskin, Y. 2002. A Plague of Rats and Rubbervines: the Growing Threat of Species Invasions. Island Press, Washington, D.C.

Bean, M.J., and M.J. Rowland. 1997. The Evolution of National Wildlife Law, 3rd ed. Praeger, Westport, Conn.

Cox, G.W. 1999. Alien Species in North America and Hawaii: Impacts on Natural Ecosystems. Island Press, Washington, D.C.

Ebbert, S. 2000. Successful eradication of introduced Arctic foxes from large Aleutian Islands. Pp. 127-132 *in* T.P. Salmon and A.C. Crabb, eds., Proceedings of the 19th Vertebrate Pest Conference. University of California-Davis, Davis.

Enserink, M. 2002. West Nile's surprisingly swift continental sweep. Science 297:1988-1989.

Gergely, K., J.M. Scott, and D. Goble. 2000. A new direction for the U.S. National Wildlife Refuges: the National Wildlife Refuge System Improvement Act of 1997. Natural Areas Journal 20:107-118.

Hendee, J.C., and C.P. Dawson. 2002. Wilderness Management: Stewardship and Protection of Resources and Values. 3rd ed. Fulcrum, Golden, Colo.

Marler, M. 2000. A survey of exotic plants in federal wilderness areas. Pp. 318-327 *in* D.N. Cole, S.F. McCool, W.T. Borrie, and J. O'Louglin, comps., Wilderness Science in a Time of Change Conference—Volume 5: Wilderness Ecosystems, Threats, and Management; May 23-27, 1999; Missoula, Montana. Proceedings RMRS-P-15-VOL-5. U.S. Department of Agriculture, Rocky Mountain Research Station, Ogden, Utah.

National Institute of Invasive Species Science (NIISS). 2004. U.S. Department of the Interior, Geological Survey. Retrieved on September 27, 2004 from the World Wide Web. Available online <http://www.niiss.org/>.

Pimentel, D., L. Lach, R. Zuniga, and D. Morrison. 2000. Environmental and economic costs of nonindigenous species in the United States. BioScience 50:53-65.

Simberloff, D., D.C. Schmitz, and T.C. Brown. 1997. Strangers in Paradise: Impact and Management of Nonindigenous Species in Florida. Island Press, Washington, D.C.

U.S. Department of Agriculture. 2002. PLANTS database. Retrieved on December 17, 2003 from the World Wide Web. Available online <http://plants.usda.gov/>.

U.S. Fish and Wildlife Service. 1999. Fulfilling the promise: the National Wildlife Refuge System. U.S. Department of the Interior, Washington, D.C.

Wilcove, D.S., D. Rothstein, J. Dubow, A. Philips, and E. Losos. 1998. Quantifying threats to imperiled species in the United States. BioScience 48:607-615.

Williams, E.S., M.W. Miller, T.J. Kreeger, R.H. Kahn, and E.T. Thorne. 2002. Chronic wasting disease of deer and elk: a review with recommendations for management. Journal of Wildlife Management 66:551-563.